# Infrared Photometry of a Helium Star, HD 30353

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**Abstract**

Infrared data for HD 30353, a helium-rich, single-lined spectroscopic binary ($T_e \sim 11{,}000°$K, $\log g \sim 1$ for primary), are presented. The infrared colors suggest that the invisible component may be a K0-type supergiant. The large $K-L$ index implies additionl infrared radiation—possibly arising in a circumstellar envelope like that found for $\upsilon$ Sgr.

## 1. *Introduction*

HD 30353 is a helium-rich star (BIDELMAN 1950; NARIAI 1963 a, b, 1967) and is also recognized as a single-lined spectroscopic binary. The orbit has been given by BIDELMAN (1950) and revised by HEARD (1962). Semi-regular light variation was reported by BAKOS (HEARD 1962) and confirmed by OSAWA, NISHIMURA and NARIAI (1963). When compared with other helium stars, HD 30353, as Well as $\upsilon$ Sgr, are peculiar since nitrogen is found to be more abundant than carbon (WALLERSTEIN, GREENE, and TOMLEY 1967; HACK and PASINETTI 1963). Table 1 summarizes the known data for this star.

TABLE 1. Data for HD 30353.

a) Orbital Parameters (HEARD 1962)

| | |
|---|---|
| Period | $360^{d}47 \pm 1^{d}07$ |
| Eccentricity | $0.28 \pm 0.03$ |
| Angle of Periastron | $268.4° \pm 0.03°$ |
| Periastron Passage | JD $2435141^{d}06 \pm 5^{d}74$ |
| Velocity Amplitude | 51.4 km/sec ± 1.6 km/sec |
| Velocity of the System | +7.0 km/sec ± 1.0 km/sec |
| $a \sin i$ | $2.43 \times 10^{8}$ km $\pm 0.08 \times 10^{8}$ km |
| Mass Function | $4.41\, M_{\odot} \pm 0.44\, M_{\odot}$ |

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b) Physical State of the Atmosphere
(NARIAI 1967; WALLERSTEIN, GREEN and TOMLEY 1967)

| | |
|---|---|
| $T_e$ | $11{,}000°K \pm 1{,}000°K$ |
| $\log g$ | $1 \pm 1$ |
| $N_N/N_{He}$ | $3 \times 10^{-5}$ |
| $N_{metal}/N_{He}$ | $10^{-2} \sim 10^{-3}$ ($N_{metal}/N_{He}$) in $\alpha$ Cyg |
| $N_C/N_N$ | $1 \times 10^{-3}$ |
| $N_O/N_N$ | $2 \times 10^{-2}$ |

c) Variablity
(OSAWA, NISHIMURA and NARIAI 1963)

| | Average | Semi-amplitude |
|---|---|---|
| $V$ | $7^m.84$ | $0^m.07$ |
| $B-V$ | 0.47 | 0.02 |
| $U-B$ | −0.18 | 0.03 |

## 2. *The Unseen Companion*

Regarding the invisible component of HD 30353, two cases would be possible. First, this component could be a B-type main-sequence star. In this case, the surface brightness of both components is about the same, but the large difference in the radii makes the secondary invisible. The other possibility is that the companion is a red giant or supergiant—in which case, due to its intrinsic redness, it could be detected only in the infrared.

In order to resolve this question, we undertook infrared observations of HD 30353 at four wavelengths $1.25\,\mu$(J), $1.6\,\mu$(H), $2.2\,\mu$(K), and $3.4\,\mu$(L). The results of three observations, made with the facilities of the Lunar and Planetary Laboratory of the University of Arizona, are presented in Table 2a. We also obtained UBVRI observations on two nights, September 7 and October 9, 1967. Since this star is variable (OSAWA, NISHIMURA and NARIAI 1963), two random observations may not yield good mean values; yet the color indices from these two measures are in good agreement and the mean values, given in Table 2b, are sufficiently accurate to illustrate the overall energy distribution.

TABLE 2. Photometric Data.

a) Infrared Data for HD 30353
(Means of 3 observations—mean epoch: Oct. 6, 1967)

| | |
|---|---|
| $K =$ | $6.03^m$ |
| $J-K =$ | $+0.45$ |
| $H-K =$ | $+0.24$ |
| $K-L =$ | $+0.48$ |

b) UBVRI Data for HD 30353
(Mean colors of two observations made on Sept. 7 and Oct. 9, 1967)

| | |
|---|---|
| $U-V =$ | $+0.30$ |
| $B-V =$ | $+0.44$ |
| $V-R =$ | $+0.56$ |
| $V-I =$ | $+0.94$ |

## 3. *Discussion*

Figure 1 shows the $V-X$ color for HD 30353, as well as $\upsilon$ Sgr and four standard stars of different spectral types—A0V, K0I, M0I, and M5I. The standard star colors were taken from JOHNSON (1966). Since the average V magnitude from Table 1 has been used to compute the colors of HD 30353, some uncertainty (denoted by the dotted portion from $I$ to $J$) is introduced in this plot. Yet, we believe that it is a meaningful representation of energy distribution and is adequate for the purposes intended here.

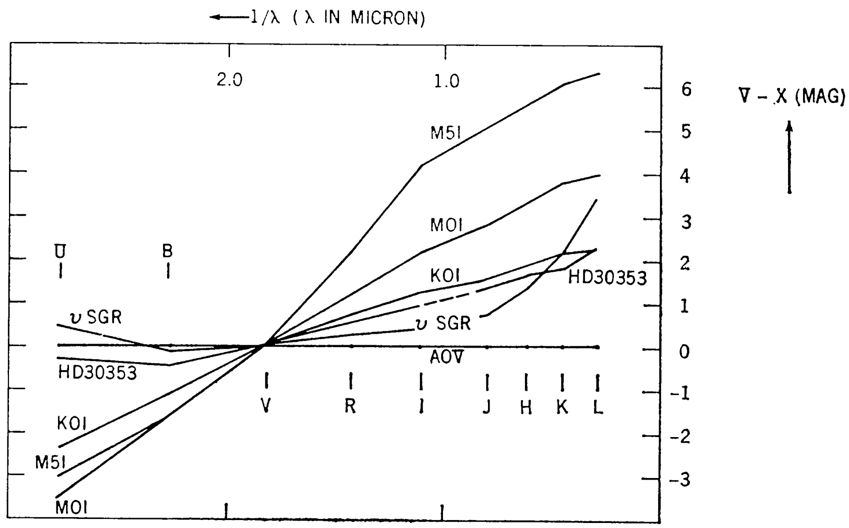


FIG. 1. The colors of HD30353, $\upsilon$ Sgr and other normal stars of different types.

Figure 1 suggests that the primary component is dominating the UBV spectral region, while in the red and infrared only the secondary is seen. The infrared colors are very similar to those of a K0-type star but due to interstellar extinction, which is about two magnitudes at B (NARIAI 1967), the type may be slightly earlier. If we assume that the radiation from the two components is equal at about 6,000A, we can estimate the radii of the stars from the relation

$$\frac{R_2^2 B(\lambda_0, T_2)}{R_1^2 B(\lambda_0, T_1)} = 1 ,$$

where the subscripts 1 and 2 denote the primary and secondary, $R$ is the radius, $T$ is the temperature, $B(\lambda, T)$ is the Planck function and $\lambda_0=6{,}000$ A. Using $T_1=11{,}000$°K (NARIAI 1967) and $T_2=5{,}000$°K for the K0 star, we find $R_2 \sim 4R_1$. The primary was analyzed spectroscopically by NARIAI (1967), who found it to be a supergiant ($\log g=1$). Therefore, we conclude that the secondary is also a supergiant whose spectral type is K0 or slightly earlier.

This result is in good agreement with earlier work by one of the authors (NARIAI 1967), who predicted that the secondary component of HD 30353 could be a supergiant with a spectral type earlier than K5. His analysis was based upon the orbital parameters of HEARD (1962),

$$\frac{(M_2 \sin i)^3}{(M_1+M_2)^2}=4.4\,M_\odot \quad \text{and} \quad a \sin i=2.43\times 13^8\ \text{km}\ ,$$

together with plausible assumptions regarding the masses and the radius ratio, $R_2/R_1$ as well as the fact that the radius of the secondary cannot exceed the distance from the center of the secondary to the Lagrangian point (see NARIAI 1967 for details). Our present infrared data justify these assumptions and verify his basic conclusion.

The $K-L$ index of HD 30353, $+0.48^m$, deserves additional comment as it is more than $0.3^m$ redder than that of a normal K0-type supergiant (JOHNSON 1966). In a study of $\upsilon$ Sgr (LEE and NARIAI 1967), the authors found strong infrared radiation (see Figure 1) whose origin was attributed to a cool interstellar gas. Since HD 30353 and $\upsilon$ Sgr have many common characteristics (hydrogen deficiency, duplicity with long period, large mass function, and H$\alpha$ emission), the $K-L$ excess is not surprising. Although the excess is not as large as that found for $\upsilon$ Sgr, it is likely that it also is due to infrared radiation from circumstellar matter.

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